TITLE OF INVENTION

Optical Netw rk M nit ring System

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

BACKGROUND OF THE INVENTION

1. Field of Invention

[0003] This invention pertains to a system for monitoring and testing optical networks. More particularly, this invention pertains to an apparatus at the physical layer of an optical network that selects one of the numerous channels and routes the optical signal to various test equipment.

2. Description of the Related Art

[0004] Optical transmission systems, as characterized by SONET (Synchronous Optical Network), SDH (Synchronous Digital Hierarchy) and others, are managed, groomed, characterized, routed, protected, and restored by switching systems at layer one or two. Layer one, the physical layer, or optical layer, is typically treated as a passive system, and is created 100% redundant due to the need for "SONET level" dynamics, which are 10 msec at layer one and 50 msec at layer two.

[0005] There is a need for optical dynamics at layer one to free up these reserved resources, which would also aid to reduce operating expenses and capital expenses. The World's data traffic is growing at 100% per year while revenue per bit is dropping as much as 50% per year. Maximizing SONET reserved resources for data traffic while maintaining SONET level robustness is one of the few options available to the carriers to solve this dilemma.

[0006] Various devices exist for performing specific aspects of optical network control. Examples of such devices include United States Patent Number 6,430,335, titled "Network Healing Smart Fiber Optic Switch," issued to Carberry, et al., on August 6, 2002, discloses a device that switches optical signals based upon degradation or complete failure of one signal. United States Patent Number 5,726,788, titled "Dynamically Reconfigurable Optical Interface Device Using an Optically Switched Backplane," issued to Fee, et al., on March 10, 1998, discloses an apparatus for dynamically reconfiguring a telecommunications network when a failure occurs.

BRIEF SUMMARY OF THE INVENTION

[0007] A system for monitoring and managing optical networks is provided. A processor controls an optical switch coupled to the physical layer of an optical network. The switch routes optical signals to selected test devices for monitoring and testing various optical parameters. The processor controls a routing switch that routes traffic in the network based on test results obtained by testing various optical parameters.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0008] The above-mentioned features of the invention will become more clearly understood from the following detailed description of the invention read together with the drawings in which:

Figure 1 is a one-line diagram of one embodiment of the apparatus;

Figure 2 is a diagram of one embodiment of the optical connections from the couplers to the test devices; and

Figure 3 is a flow diagram of one embodiment of the functions performed by the processor.

DETAILED DESCRIPTION OF THE INVENTION

[0009] A system, generally shown as **10** on the figures, for monitoring and managing optical networks is disclosed. The system is configurable for both single mode and multimode functionality. The system, in various embodiments, performs one or more of the following functions within the physical layer of an optical network. First, the system optically monitors a large number of optical channels with a common control and testing system through the use of optical switches in an Nx1 array, which combines many Nx1 switch arrays through couplers.

[0010] Second, the system distributes the optically selected channel to an array of test equipment through an 1xN switch. Equipment to which the selected monitored channel is directed by this 1xN switch includes bit error measurement, spectrum analysis, chromatic dispersion, polarization mode dispersion measurement (PMD), power, reflection, and optical time domain reflectometer (OTDR) measurements, among others. The system provides alarms and messages and reroute traffic based upon previously established performance thresholds.

[0011] Third, the system manages the monitoring pattern both with regard to the pattern and schedule in which the various channels are monitored, including the pattern and schedule in which the selected channels are tested because, in select embodiments, the various tests are performed on discrete schedules and patterns.

[0012] Fourth, the system collects and characterizes the test data in real time, and provides real time historical test data in various reports. Fifth, the system provides alarm functions through network interfaces based on discrete or pattern programmed thresholds. Sixth, the system provides network healing functions. Seventh, the system provides grooming though the use of switches for protection, restoration, hot spare management, bandwidth management, etc. Eighth, the system provides the platform of awareness and dynamics that allows the use of SONET/SDH reserved and idle resources for transmission of traffic while still providing the basis of SONET required level of service on a majority of the physical network.

[0013] Figure 1 illustrates a one-line diagram of the system **10** attached to an optical network **102**, which is illustrated as having two sections identified as **102a**, **102b** with portions of the apparatus **10** between the two network sections **102a**, **102b**. In general, the apparatus **10** monitors the optical signals carried through an optical network **102**, such as a synchronous optical network (SONET) or a synchronous digital hierarchy network (SDH), which includes a multitude of optical fiber pathways. A coupler **104**, such as a planer wave guide circuit or fused biconic taper device, taps the optical network **102** and provides about 1 to 10% of the optical signal on the network. Placement of the coupler **104** in the optical network **102** is not critical. In one embodiment, the coupler **104** is placed before the receivers.

[0014] The coupler **104** taps into the network cables **102a** adjacent a switch **106**, which is controlled by a processor **112**. The switch **106**, in one embodiment, provides routing of the various optical signals on the network **102** based on various parameters monitored by the processor **112**. The switch **106**, in another embodiment, includes tunable filters, Bragg gratings or thin film filters for manipulating and routing discrete wavelengths among the various optical fiber cables forming the network **102**. The switch **106**, in still another embodiment, provides operational flexibility though the use of a combination of optical switches for protection, restoration, hot spare management, and bandwidth management.

[0015] The output optical signals from the coupler **104** are routed to a coupler switch, or coupler selector switch, **108**, which routes the tapped optical signals through a receiver amplifier/attenuator **118** to various test devices **110**. The coupler selector switch **108** is controlled by the processor **112** and the test devices **110** provide test result data to the processor **112**. The amplifier **118** provides, in one embodiment, positive amplification, such as by a receiver amplifier, to boost the optical signal to the level required by specific test devices **110**. In another embodiment, the amplifier **118** provides negative amplification, such as through a variable optical attenuator or other attenuator, to match the level required by specific test devices **110**.

[0016] The processor **112** monitors the results of the test devices **110** and controls the switches **106**, **108** and amplifier **118**. The processor **112** also provides alarms **114** for out-of-specification optical performance and connects to remote services **116**, such as remote terminals and other processors and systems. In various embodiments, the alarms **114** include an annunciator board, either through a computer display or a physical annunciator, showing the equipment being used to monitor the various channels, including the results and conformance or non-conformance, as well as a display showing any alarms by channel and function. The processor **112** includes software and routines for collecting, storing, characterizing, and profiling the results from the test devices **110**. In addition, the processor **112** includes software and routines for controlling the optical switches **106**, **108** to select and route optical channels. As used herein, the processor **112** should be broadly construed to mean any computer or component thereof that executes software.

[0017] Figure 2 illustrates the optical connections from the couplers **104**, through the coupler selector switch **108**, the receiver amplifier/attenuator **118**, and into the test devices **110**. The illustrated embodiment shows three couplers **104a**, **104b**, **104c** that tap into the network cables **102**. Those skilled in the art will recognize that the number of couplers **104** will vary with the number of optical cables **102** to be monitored. The tapped signals are input to a coupler selector switch **108**, which selects one of the signals to route to the amplifier **118** and test devices **110**. In one embodiment, the coupler selector switch **108** is an Nx1 switch, that is, it has a selected number of inputs (N) that are switched to one output. In another embodiment in which the number of tapped signals exceeds the number of inputs to a single Nx1 switch, the coupler selector switch **108** is a bank of Nx1 switches connected to one or more Nx1 switches.

[0018] The test devices **110** include a test switch **202**, which in one embodiment is a 1xN switch, that switches the single optical signal to any one of the selected test equipment **204**. In the illustrated embodiment, the test equipment **204** include monitoring of binary error rate (BER) **204a**, spectrum analysis (SA) **204b**, insertion loss (ILoss) **204c**, return/reflectance loss (RLoss) **204d**, and dispersion **204e**. Those skilled in the art will recognize that the test

equipment **204** can include any of a multitude of optical testing and monitoring equipment without departing from the spirit and scope of the present invention.

[0019] The amplifier **118** functions to increase or decrease the optical signal intensity to match the input signal requirements of each test equipment **204**. In one embodiment, the optical signal strength is increased by a receiver amplifier. In another embodiment, the optical signal strength is decreased by an attenuator. In yet another embodiment, a variable attenuator adjusts the optical signal strength to the desired level. In still another embodiment, the amplifier **118** includes both a receiver amplifier and an attenuator to selectively adjust the optical signal strength.

[0020] In the illustrated embodiment, the amplifier **118** is located between the coupler switch **108** and the test switch **202**. In another embodiment, each test device **204** has an amplifier **118** to match the optical signal strength to the particular test device **204**.

[0021] Figure 3 illustrates one embodiment of the functions performed by the processor **112** with respect to testing. These functions are described as steps to be performed. The first step is to determine the channel to test **302**. A channel represents an optical signal from a coupler **104**. In one embodiment, a channel is an optical signal from a single optical cable **102**. In another embodiment, a channel is a discrete wavelength from an optical cable **102** that contains one or more optical signals. In this embodiment, the discrete wavelength is separated from the others by a tunable filter, a Bragg grating, or a thin film filter after the coupler **104** and before the coupler selector switch **108**. In one embodiment, the channels are sequentially selected for testing. In another embodiment, the channels are sequentially selected for testing, and channels that return marginal results or otherwise indicate that more frequent testing is desired, are tested more than once per sequential loop.

[0022] After determining the channel to test **302**, the next step is to select the channel **304** to be tested. In one embodiment, selecting the channel **304** involves operating the coupler selection, or channel selection, switch **108**, which is an Nx1 switch, to select the channel for testing. In another embodiment, the

number of channels is greater than can be switched by a single Nx1 switch; therefore, the switch **108** includes an array of Nx1 switches with the outputs of one bank of Nx1 switches feeding the inputs to one or more Nx1 switches.

[0023] After selecting the channel **304**, the next step is to select the test **306**. In one embodiment, the tests are selected sequentially. In another embodiment, the tests are selected sequentially, and channels that return marginal results for a particular test or otherwise indicate that more frequent testing is desired, have a test performed more frequently. In one embodiment, selecting the test **306** involves operating the switch **202**, which is a 1xN switch, to select the test equipment **204** desired. In another embodiment, the number of test equipment **204** exceeds the number of outputs than can be switched by a single 1xN switch; therefore, the switch **202** includes an array of 1xN switches with the outputs of one 1xN switch feeding the inputs to a bank of 1xN switches.

[0024] After selecting the test **306**, the next step is to set the amplification or attenuation **308** to match the input signal level to the signal level required by the test equipment **204**. In one embodiment, setting the amplification or attenuation **308** is performed before switching the test equipment **204**, which prevents an optical signal with an improper level from being seen by the test equipment **204**. In one embodiment, setting the amplification or attenuation **308** is performed as illustrated in Figure 2, that is, before the optical signal is passed through the coupler selector switch **202**.

[0025] After the test signals are set up, the next step is to initiate the test **310**. The test equipment **204** is computer controlled, that is, a processor **112** communicates with the test equipment **204** for both sending control signals, receiving status data, and receiving acquired test data. In one embodiment, the processor **112** communicates over a local area network. In another embodiment, the processor **112** communicates with the test equipment **204** over dedicated lines, such as serial or parallel cables. Those skilled in the art will recognize that the processor **112** can communicate with the test equipment **204** in any of various ways without departing from the spirit and scope of the present invention.

[0026] After the test is initiated **310**, the next step is to save the results **312**. In one embodiment, the results are saved **312** by the processor **112**. In one embodiment, the processor **112** includes a memory storage component, such as a floppy disk, a hard disk, or a writable optical disc, onto which the test results are saved. In another embodiment, the processor **112** accesses an external memory storage unit onto which the test results are saved.

[0027] After the test results are collected by the processor **112**, the test results are evaluated as to whether they are within specifications **314**. The evaluation determines whether corrective action is required, and more specifically, depending upon the test being performed and the results of that test and previous tests, a specific corrective action may be warranted. In one embodiment, the test results are evaluated **314** after being saved **312**. In another embodiment, the evaluation **314** occurs simultaneously with the saving of the test results **312**. In one embodiment, the test results are evaluated **314** by comparing the test results to baseline data. In another embodiment, the test results are evaluated **314** by comparing the test results to threshold values. In one embodiment, the threshold values are preselected values. In another embodiment, the threshold values are based on previous test results and are adjusted based on trend data collected. In still another embodiment, the threshold values are based on the configuration of the system and the availability of spares.

[0028] If the test results are within specifications **314**, the cycle repeats. That is, in the illustrated embodiment, the next channel to test is determined **302**. In another embodiment, after one test is completed, the next test is selected **306**. After all the tests are run, the next channel to test is determined **302**.

[0029] If the test results are not within specifications **314**, the next step is to initiate corrective action **316**. The determination of the specific corrective action occurs during the evaluation of the results **314**. The corrective action initiated **316** includes, in various embodiments, one or more of the following actions: a) send an alarm by a recorded telephone message to any of one or more telephone numbers, b) send an alarm through the network to any of a variety of alarms **114** and remote services **116**, c) send a message to other systems or remote services

116 to request optical or layer two response to a failure or risk of failure, and/or d) optically reroute the channel in question, based on the type of test and how far the test results were out of specification. In one embodiment, optical rerouting of the channel is accomplished via the switch **106** on the optical network **102**.

[0030] In various embodiments, the switch **106** includes one or more network healing smart switches, spare sources that can be switched into the network **104** and replace a failed or faulty channel, switches for rerouting fibers through other fibers, switches for rerouting through alternate wavelengths, and switches for rerouting traffic through channels shutdown because the channels were carrying lower guaranteed quality of service (QOS). In one embodiment, the switch **106** is a combination of various Nx1, 1xN, and NxN optical switches that allow the switching to be performed at layer 1 of the optical network.

[0031] In one embodiment, each of the functions identified in Figure 3 are performed by one or more software routines run by the processor **112**. In another embodiment, one or more of the functions identified in Figure 3 are performed by hardware and the remainder of the functions are performed by one or more software routines run by the processor **112**. In still another embodiment, the functions are implemented with hardware, with the processor **112** providing routing and control of the entire integrated system **10**. Those skilled in the art will recognize that it is possible to program a general-purpose computer or a specialized device to implement the invention.

[0032] The processor **112** executes software, or routines, for performing various functions. These routines can be discrete units of code or interrelated among themselves. Those skilled in the art will recognize that the various functions can be implemented as individual routines, or code snippets, or in various groupings without departing from the spirit and scope of the present invention. As used herein, software and routines are synonymous. However, in general, a routine refers to code that performs a specified function, whereas software is a more general term that may include more than one routines or perform more than one function.

[0033] The processor **112** should be broadly construed to mean any computer or component thereof that executes software. In one embodiment the processor **112** is a general purpose computer, in another embodiment, it is a specialized device for implementing the functions of the invention. Those skilled in the art will recognize that the processor **112** includes an input component, an output component, a storage component, and a processing component. The input component receives input from external devices, such as the test equipment **104** and remote services **116**. The output component sends output to external devices, such as the coupler switch **108**, the test device switch **202**, alarms **114**, and remote services **116**. The storage component stores data and program code. In one embodiment, the storage component includes random access memory. In another embodiment, the storage component includes non-volatile memory, such as floppy disks, hard disks, and writeable optical disks. The processing component executes the instructions included in the software and routines.

[0034] The system for monitoring and testing an optical network includes various functions. The function of extracting a plurality of test signals from the optical network is implemented by the couplers **104** in the optical network **102**. The function of selecting a channel for testing, with the channel being selected from said plurality of test signals, is implemented, in one embodiment, by software running on the processor **112** and the coupler switch **108**. The function of selecting a test to perform on the selected channel is implemented, in one embodiment, by software running on the processor **112** and the coupler selector switch **202**. The function of testing is implemented by the test equipment **204**. In various embodiments, the test equipment includes one or more of a binary error rate test (BER) **204a**, spectrum analysis (SA) **204b**, insertion loss (ILoss) **204c**, return/reflectance loss (RLoss) **204d**, and dispersion **204e**. The function of evaluating a test result is implemented, in one embodiment, by software running on the processor **112**.

[0035] The function of performing corrective action is implemented, in one embodiment, by software running on the processor **112**, which determines which corrective action to take. In various embodiments, the corrective action includes one or more of sending an alarm to a telephone, sending an alarm to an alarm unit

114, sending an alarm to a remote service **116**, sending a message to the remote service **116** to request a response to a failure or risk of failure, and optically rerouting the channel in question via the network switch **106**. The function of selectively modifying the intensity is performed by the processor **112** and the amplifier **118**.

[0036] From the foregoing description, it will be recognized by those skilled in the art that a system for monitoring and managing optical networks has been provided. The system includes optical couplers, optical switches, test devices, and a processor.

[0037] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.